DOE DER Program
Peer Review

Microgrid Analysis Tools

μGRD

μT

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Presentation Outline

- Motivation and Objectives
- Analysis Tool Needs
- The µGRD Computer Model: Unique Characteristics and Capabilities
- Example Cases
- Commercialization Plan

Motivation and Objectives

- Support CERTS Microgrid Vision on DERs
- Develop a Reliable Tool for Steady State Analysis of Microgrids that:
  - Uses physically based high fidelity models
  - Incorporates DER controls and captures their interaction
  - Provides a TestBed for testing alternate designs

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Microgrid Analysis Tool: Needs

- Steady State Analysis Tool for microgrids.
- CERTS Microgrid is defined as a distribution system with DERs.
- The distribution system may contain three-wire, four-wire and five-wire circuits.
- The CERTS Microgrid may supply three phase as well as single phase loads.
- The microgrid sources (DERs) may operate under different control laws. As a matter of fact, control functions are expected to increase as manufacturers become more sophisticated.
- Commercially available tools do not address all of the above issues. The μGRD model does.

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Microgrid Analysis Tool: Needs

- The distribution system may contain three-wire, four-wire and five-wire circuits.
  - A comprehensive study by ORNL compared the capabilities of commercially available tools. While these tools offer many application functions, the basic model is based on symmetric power systems.
- The microgrid sources (DERs) may operate under different control laws. As a matter of fact, control functions are expected to increase as manufacturers become more sophisticated.
  - Commercially available tools do not address complex control functions of microsources and their interaction through a typical network (three wire, four-wire, five-wire system).

*m*GRD: Unique Characteristics

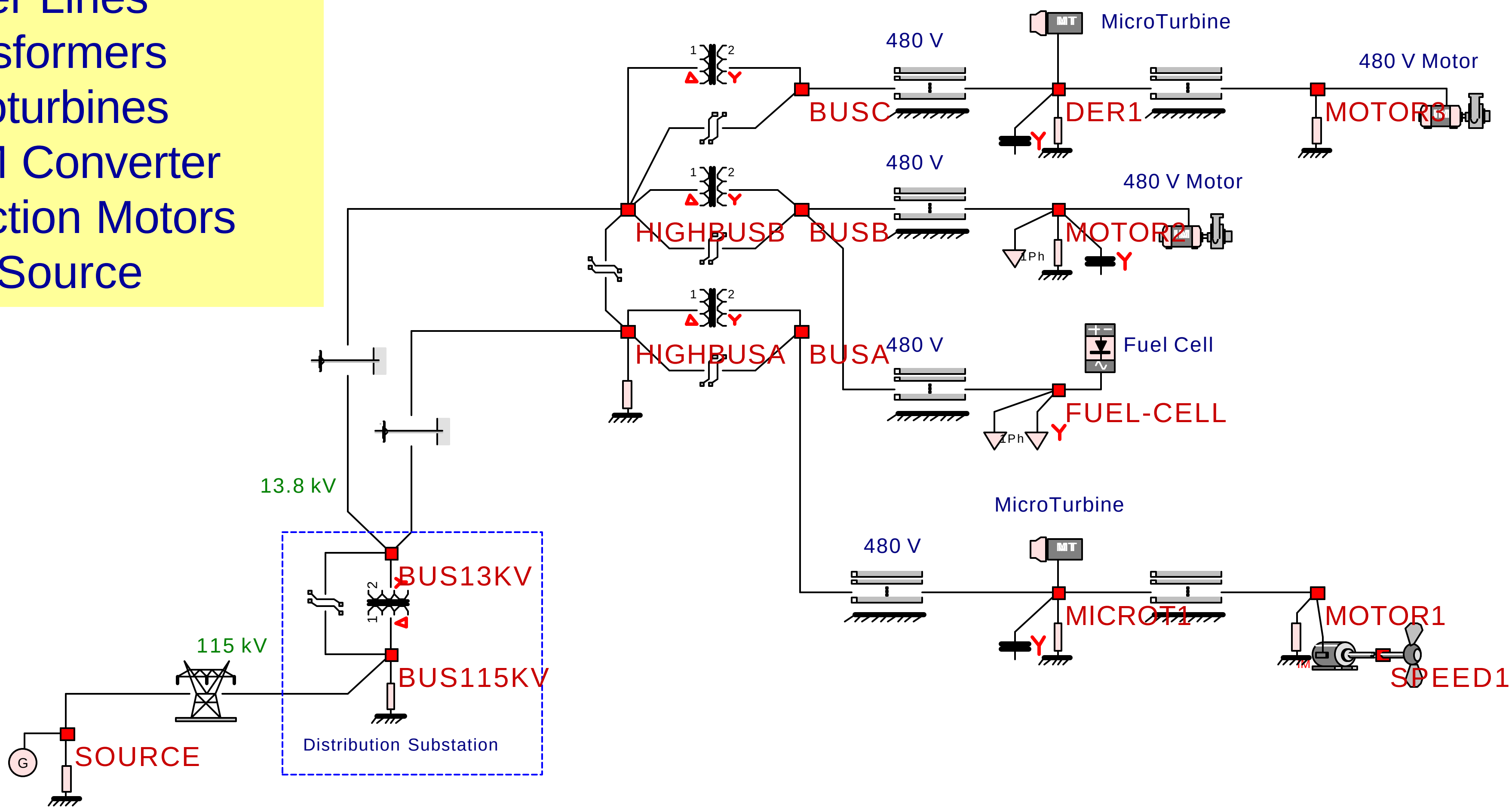
- Components are modeled in direct phase quantities without any approximating assumptions, for example symmetrical components.
  - Provides the capability of handling three wire, four-wire and five-wire systems
  - Provides high fidelity models
- Each component model is quadratized, i.e. it is expressed in terms of equations of order no higher than 2. The quadratized model is an exact representation of the component behavior for any complex and nonlinear operation of the component and its controls.
  - Provides the capability of direct solution for radial and networked systems and accurate analysis of the interaction of DER controls.

*m*GRD: Unique Characteristics

- It uses the concept of composite node. A composite node may consist of any number of nodes, for example: phase A, phase B, phase C, Neutral and Ground for a five wire circuit. It allows to model grounding and bonding arrangements and to study safety issues associated with these systems.
  - Provides the capability of handling systems that consist of any combination of three-wire, four-wire and five-wire subsystems
  - Provides the capability of directly modeling grounding and bonding arrangements
  - Opens up the ability to study safety issues in a µicroGrid.

mGRD Network Modeling Capability

Power Lines
Transformers
Microturbines
PWM Converter
Induction Motors
Grid Source



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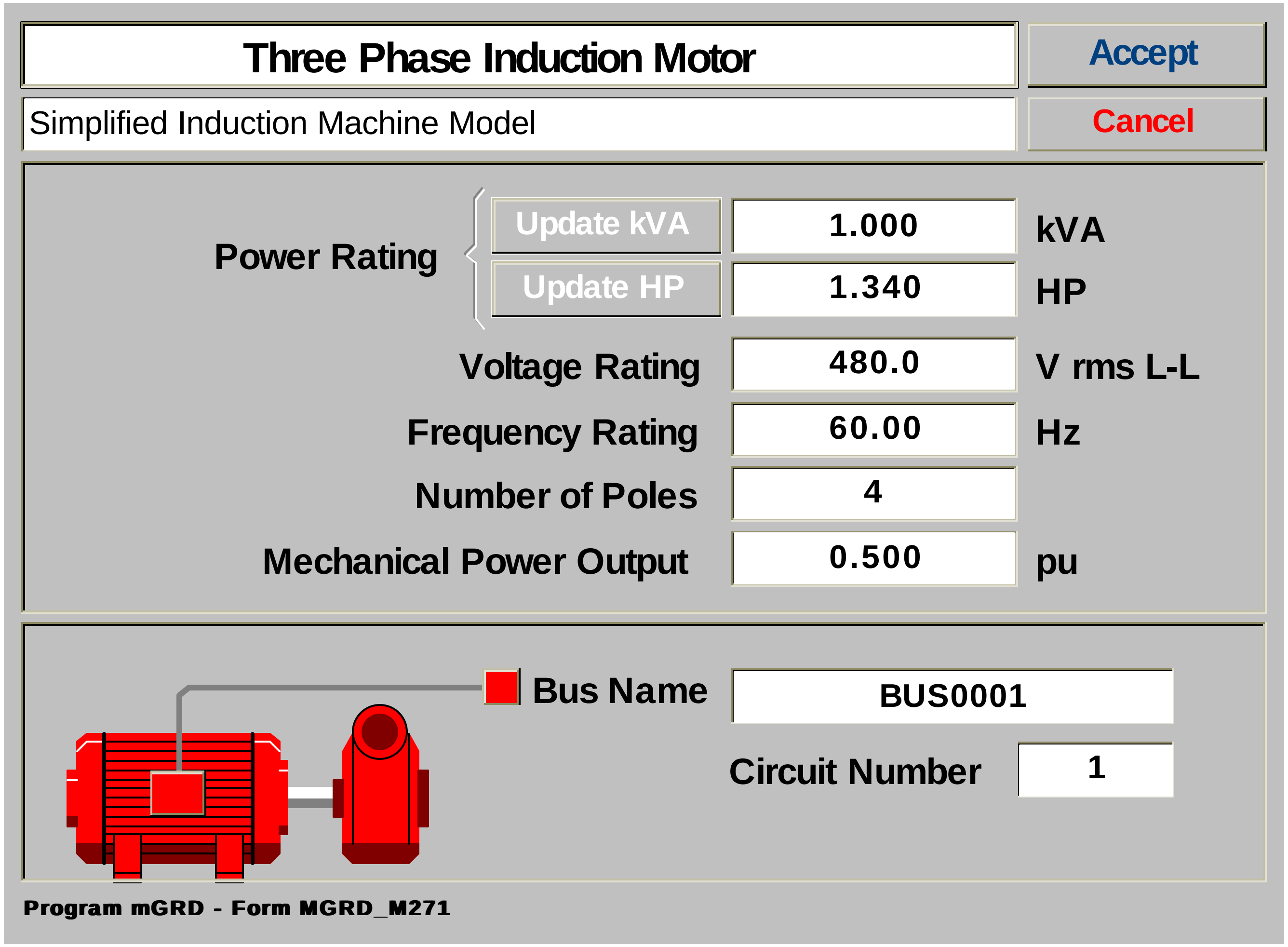
Component Example: Induction Motor


Three Phase Induction Motor

Accept

Simplified Induction Machine Model

Cancel

Power Rating — Update kVA	1.000	kVA
Power Rating — Update HP	1.340	HP
Voltage Rating	480.0	V rms L-L
Frequency Rating	60.00	Hz
Number of Poles	4	
Mechanical Power Output	0.500	pu

Bus Name: BUS0001

Circuit Number: 1

Program mGRD - Form MGRD_M271

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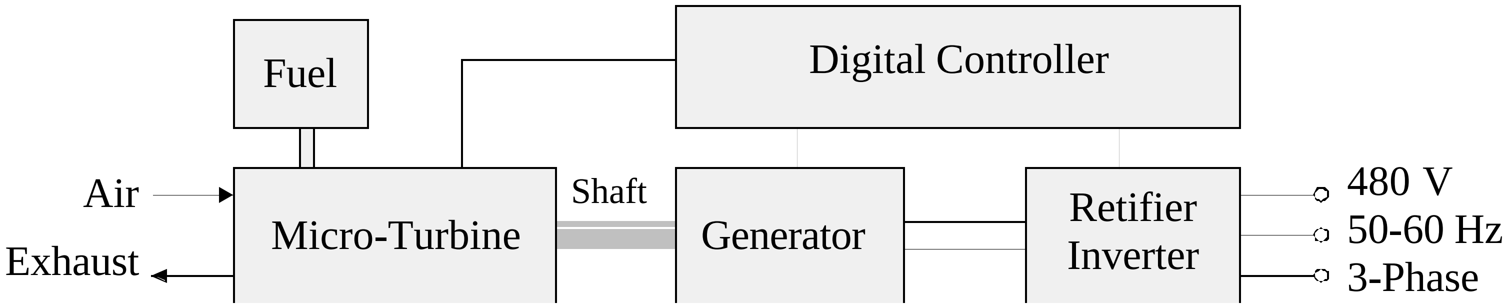
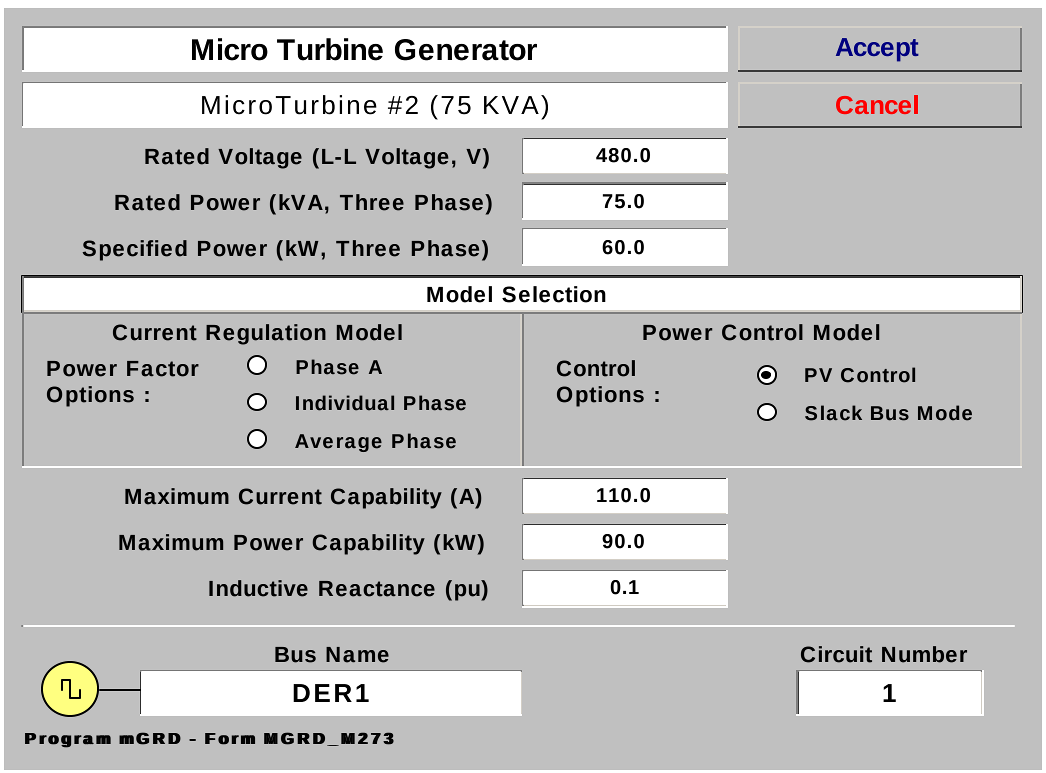
Component Example: MicroTurbine Model




Micro Turbine Generator | Accept

MicroTurbine #2 (75 KVA) | Cancel

Rated Voltage (L-L Voltage, V)	480.0
Rated Power (kVA, Three Phase)	75.0
Specified Power (kW, Three Phase)	60.0

Model Selection

Current Regulation Model

Power Factor Options :
- ○ Phase A
- ○ Individual Phase
- ○ Average Phase

Power Control Model

Control Options :
- ◉ PV Control
- ○ Slack Bus Mode

Maximum Current Capability (A)	110.0
Maximum Power Capability (kW)	90.0
Inductive Reactance (pu)	0.1

Bus Name: DER1

Circuit Number: 1

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Component Example: PWM Converter

PWM Inverter Model

PWM Converter

Accept | Cancel

Rated Voltage (L-L Voltage, V)	480.0
Rated Power (kVA, Three Phase)	100.0
Specified Real Power (kW, Three Phase)	95.0
Specified Reactive Power (kVAr, Three Phase)	0.0

Model Selection

Current Regulation (PQ Mode)

- ○ Phase A Q
- ○ Individual Phase Q
- ○ Total Q

Power Control Model

- ○ Slack Bus Mode
- ◉ PV Mode
- ○ PV Mode with Negative Sequence Control

Inductive Reactance (pu)	0.10
Maximum Current Capability (A)	140.0
Maximum Power Capability (kW)	110.0

Bus Name: FUEL-CELL   Circuit Number: 1

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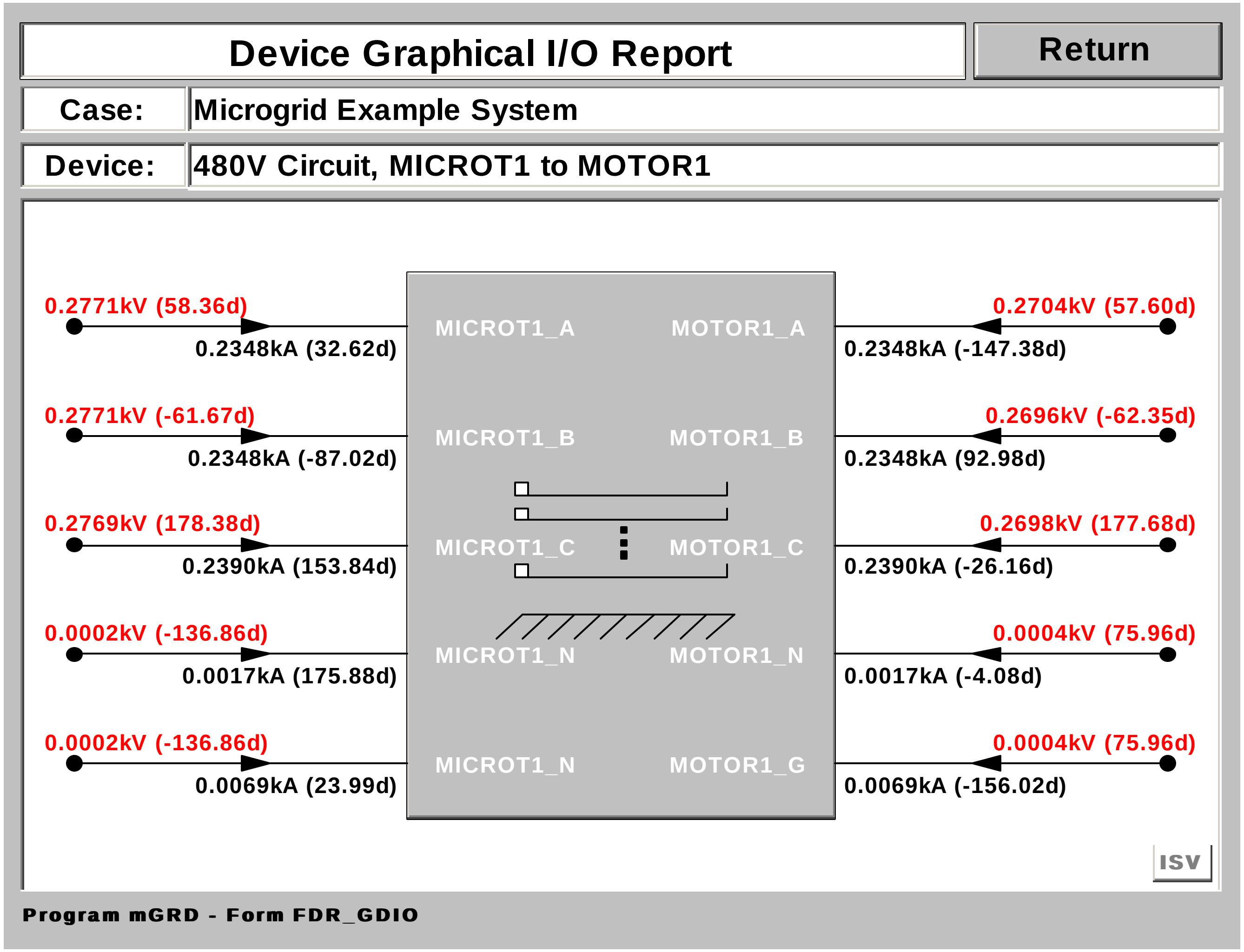
mGRD Example Report



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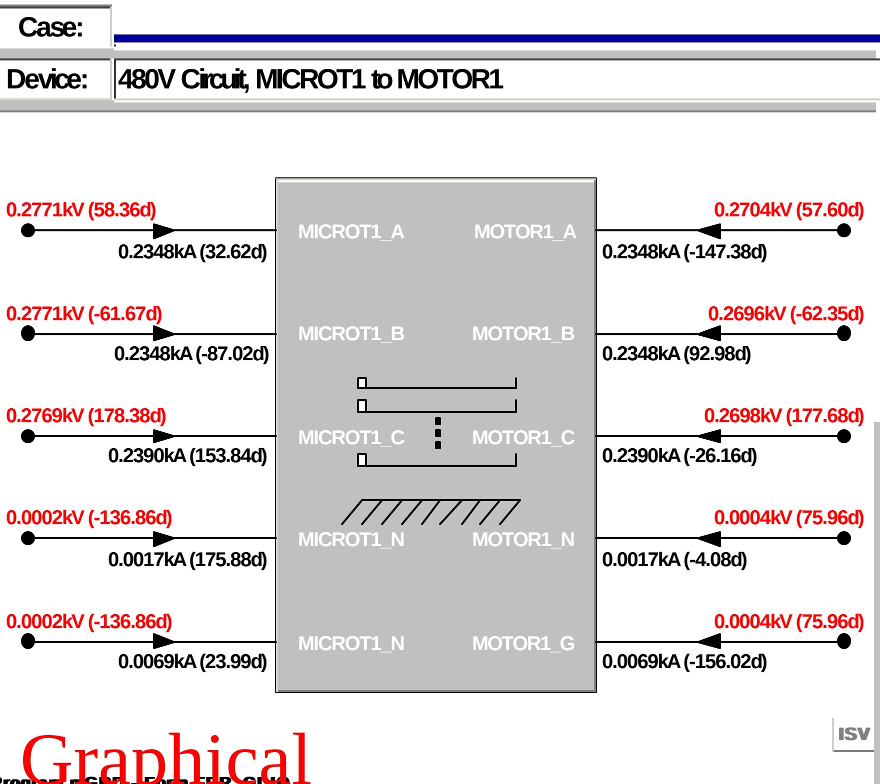
mGRD Example Report: Current Flow



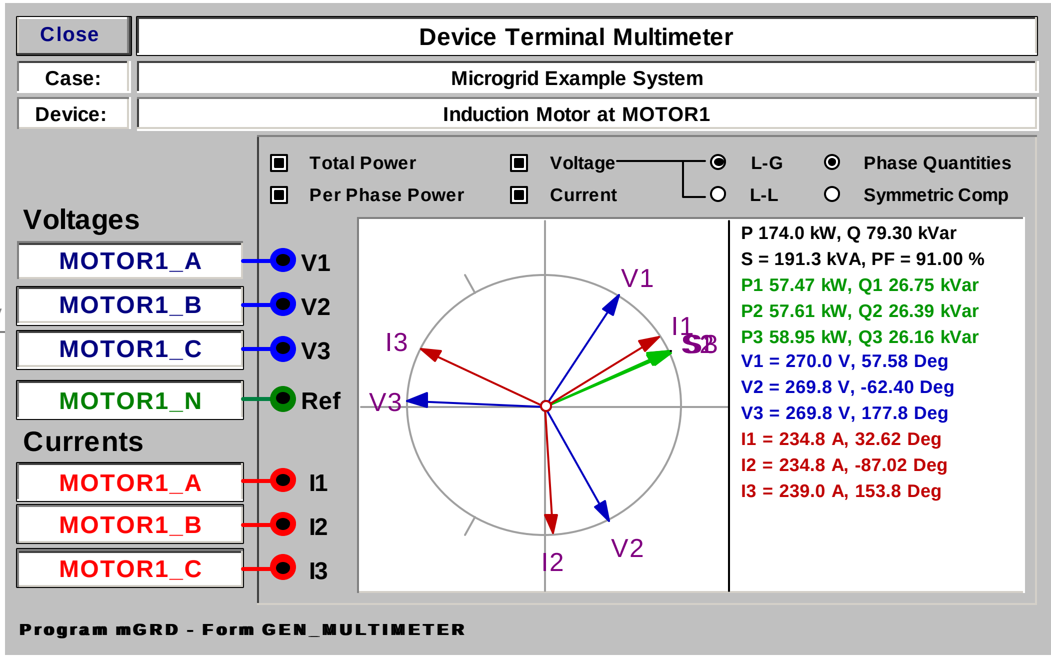
Graphical

Input/Output

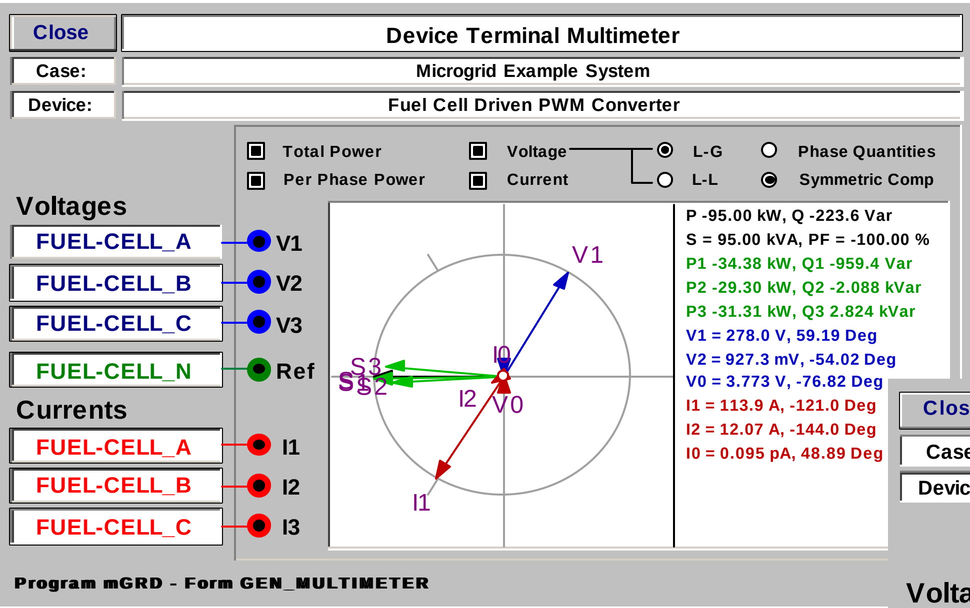
Report

Phasor and

Power Report

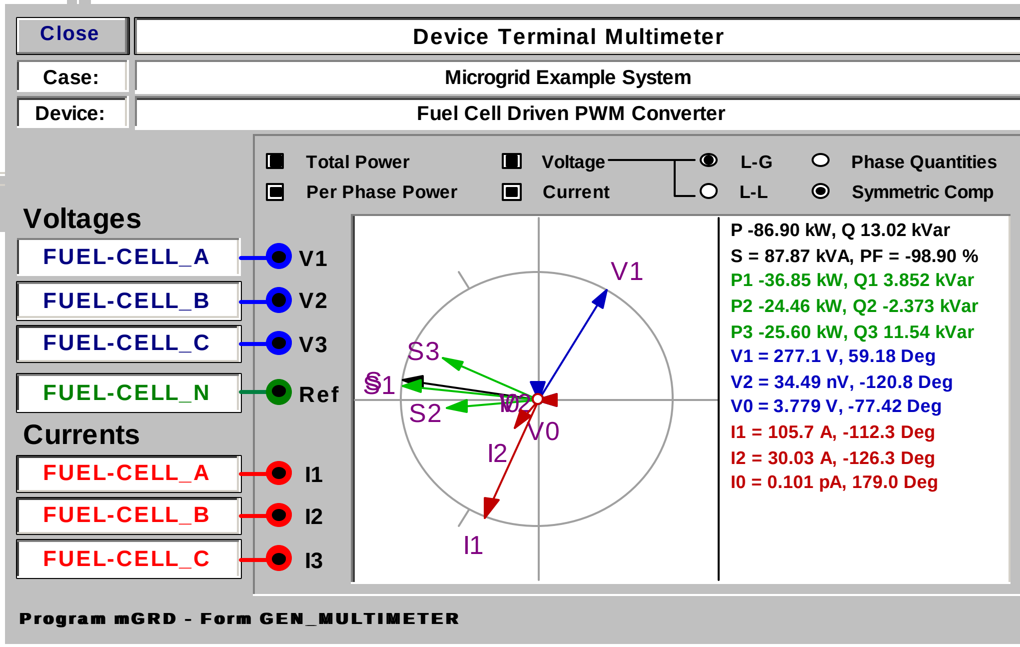


mGRD Application Ex: Negative Seq. Control



Solution with Fuel Cell in Negative Seq. Control

Solution with Fuel Cell in PV Mode



Sequence Values Report

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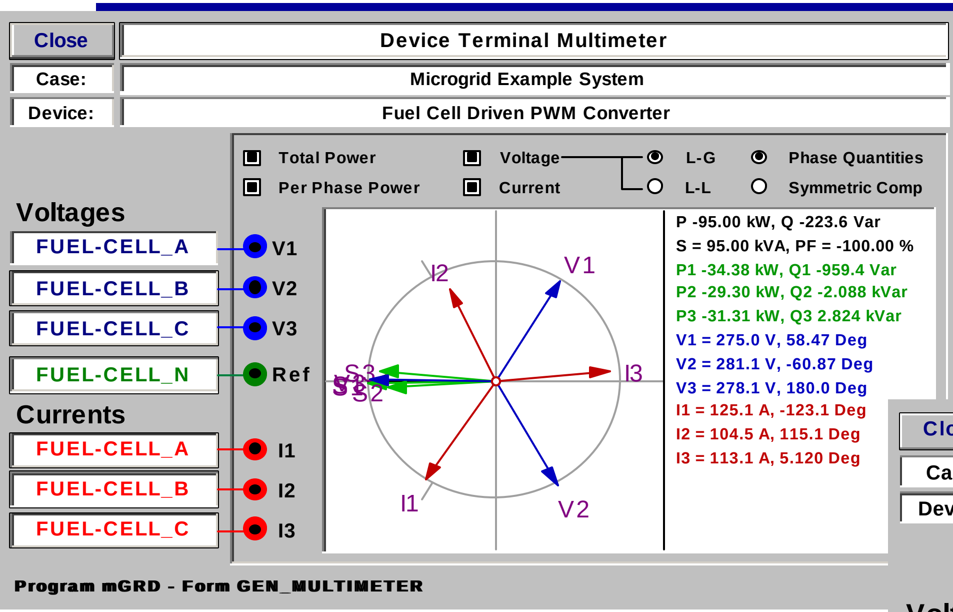
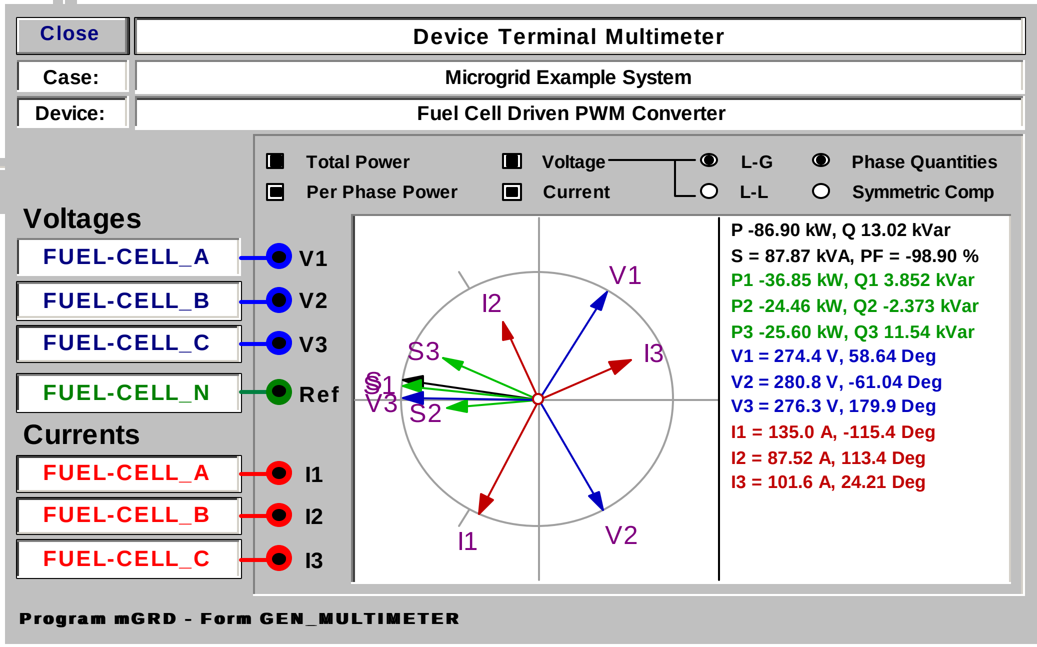
mGRD Application Ex: Negative Seq. Control



Solution with Fuel Cell in Negative Seq. Control



Solution with Fuel Cell in PV Mode

Actual Values Report

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Steps Toward Commercialization

- The μGRD computer model is a useful tool with unique capabilities
- Utilization of the μGRD computer model on a commercial basis will require: (a) increased modeling capability and (b) additional applications functions
- Proposed Steps Towards Commercialization: The following steps are proposed:
  - Integrate the μGRD computer model with the GEMI computer model
  - Develop additional applications functions: Fault Analysis, DER dispatch, Loss minimization monitoring, Time-sequence operation, Visualization and Animation tool of μGRD operation, and other.

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Project Status

- A prototype computer model has been developed: Program μGRD
- A draft final report was issued that describes the μGRD tool and the associated models. The report has been revised and finalized (with comments received from reviewers).
- Several technical papers have been published or will be published (see next slide).
- Future plans:
  - Promote utilization of the μGRD tool in the DoE/CERTS/DER program as well as in the industry
  - Enhance the modeling capability of the tool (by adding more models) and supported applications
  - Formulate commercialization plans

Publications

A. P. Sakis Meliopoulos, “Distributed Energy Sources: Needs for Analysis and Design”, *Proceedings of the 2001 IEEE/PES Summer Meeting*, Vancouver, BC, CN, July 15-19, 2001.

A. P. Sakis Meliopoulos, “Impact of Grounding System Design on Power Quality”, *IEEE Power Engineering Review*, Vol 21, No. 11, pp 3-7, November 2001.

Nikos D. Hatziargiriou and A. P. Sakis Meliopoulos, “Distributed Energy Sources: Technical Challenges”, *Proceedings of the 2002 IEEE/PES Winter Meeting*, New York, NY, Jan 28-31, 2002.

Sakis Meliopoulos, “Challenges in Simulation and Design of mGrids”, *Proceedings of the 2002 IEEE/PES Winter Meeting*, New York, NY, Jan 28-31, 2002.

A. P. Meliopoulos, G. J. Cokkinides and Robert Lasseter, “An Advanced Model for Simulation and Design of μGrids”, to be presented at the Med Power 2002, November 2002